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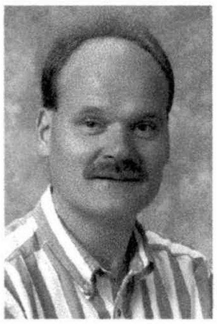

Biotechnology– Some Implications of Its Use in Agriculture

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Biotechnology involves making changes to the cellular and molecular structure of organisms. The application of biotechnology by way of genetic modification and selection to increase agricultural productivity is as old as agriculture itself. What makes modern genetic engineering–as a form of biotechnology–different from traditional means of manipulating the biology of plants and animals is the application of technology that allows for moving functional genes from one organism to another. In this commentator, the term 'biotechnology' refers to the technique used by biological scientists to modify genes within an organism or to transfer specific genes between organisms. Thus, genetic engineering facilitates the development of characteristics that are not possible through traditional breeding techniques. In this article, the terms "biotechnology," "bioengineering," and "genetic engineering" are used interchangeably, and refer to the use of modern genetic techniques to obtain "genetically modified" or "transgenic" plants and animals.

Three Phases of Biotechnology

The current set of genetically engineered products is limited to agronomic input traits that have not provided, and were not intended to give, significant benefits beyond conventional agricultural products to consumers. An example of a trait developed with the use of biotechnology is decreased pest susceptibility, which reduces the need for chemicals that prevent plant diseases and insect infestations. Other production-level traits currently being developed by genetic engineering are the ability of plants to grow under saline conditions, increased frost-tolerance levels, and improved drought-resistance abilities. Further, federal approval is currently being sought to market genetically engineered Atlantic salmon that grow to market size in half the time as normal Atlantic salmon. A second set of products, many of which have already been developed but are awaiting approval for marketing, are characterized by output traits that enhance the products' processing characteristics and have improved quality characteristics for consumption purposes. For example, this second generation of biotechnology products includes fats and starches with improved processing and digestibility characteristics. A third generation of biotechnology products is expected to have an emphasis on end user quality traits, including nutraceutical or functional foods, which are crops engineered to medicines or food supplements within plants.

Agricultural biotechnology is still in the first generation of genetically engineered products. However, innovations by way of biotechnology already appear to be on their way to becoming one of the most rapidly adopted types of technology in agricultural history. Global cropland planted with bioengineered crops increased from four million acres when the crops became commercially available in 1996, to an estimated 109 million acres in 2000, spread over 12 countries (see Table 1). The United States and Canada account for more than three-fourths of global cropland acres grown with genetically engineered crops. Much of the remaining cropland acres used for transgenic crops are located in Argentina. Other major producers of agricultural products such as Brazil and China, are also expected to become major participants in growing transgenic crops. Other nations that grow transgenic crops but are not listed in this table include Romania, Mexico, Bulgaria, Spain, Germany, France, and Uruguay.

Table 2 lists the number of cropland acres devoted to genetically engineered crops. The table shows that in 2000, soybeans accounted for approximately 58 percent of the world's cropland acres used for genetically engineered crops, followed by corn with about 23 percent, cotton with

approximately 12 percent, and canola with about seven percent of the global cropland area used for transgenic crops.

Table 1. Global Area of Transgenic Crops, by Country, 1996-2000 (Million Hectares)

Country	1996	1997	1998	1999	2000*	2000* (Percent)
United States	1.5	8.1	20.5	28.7	30.3	70.5
Argentina	0.1	1.4	4.3	6.7	8.8	20.5
Canada	0.1	1.3	2.8	4.0	3.0	7.0
China	...	<0.1	<0.1	0.3	0.5	1.2
South Africa	...	<0.1	<0.1	0.1	0.2	0.5
Australia	...	<0.1	0.1	0.1	0.2	0.5
World	1.7	11.0	27.8	39.9	43.0	100.2

* Data for 2000 are based on preliminary estimates
Source: James.

Table 2. Genetically Modified Crops Grown in 2000, by Crop, 1996-2000 2000 (Million Hectares)

Crop	1996	1997	1998	1999	2000*	2000* (Percent)
Soybeans	...	5.1	14.5	21.6	24.8	57.7
Corn	...	3.2	8.3	11.1	9.9	23.0
Cotton	...	1.4	2.5	3.7	5.2	12.1
Canola	...	1.2	2.4	3.4	3.0	7.0
Other	...	0.1	0.1	0.1	0.1	0.2
Total	1.7	11.0	27.8	39.9	43.0	100.0

* Data for 2000 are based on preliminary estimates
Source: James.

Globally, as well as in the United States, the area planted to genetically engineered crops leveled off somewhat between 1999 and 2000. Table 2 shows that cropland areas planted with transgenic soybeans and cotton increased from their 1999 levels, while the planted acreages of genetically engineered corn and canola underwent a slight decrease from their 1999 levels.

Agriculture in the Upper Midwest has been in the forefront of biotechnological advances, and some of the most controversial biotechnology products are produced in the region. Tables 3 and 4 list the extent to which transgenic corn and soybean varieties, respectively, were planted in the United States and in selected states in 2001. Approximately 26 percent of the nation's corn, and 68 percent of U.S. soybean acres was planted with bioengineered crops in 2001. Among 11 Midwestern States, South Dakota ranked first in the percentage of total cropland planted with genetically modified corn, and the state shared its number one position with Kansas in the percentage of total cropland planted with transgenic soybeans in 2001.

Table 3. Farmer Reported Genetically Modified Corn Varieties, by State and for the United States, in Percent of All Planted Corn Acres, 2001

State	% of Corn Planted
South Dakota	47
Kansas	38
Minnesota	36
Nebraska	34
Iowa	32
Missouri	32
Wisconsin	18
Michigan	17
Illinois	16
Indiana	12
Ohio	11
Other states	20
United States	26

Source: U.S. Department of Agriculture.

Table 4. Farmer Reported Genetically Modified Soybean Varieties, by State and United States, in Percent of All Planted Soybean Acres, 2001

State	% of Soybeans Planted
South Dakota	80
Kansas	80
Indiana	78
Nebraska	76
Iowa	73
Missouri	69
Ohio	64
Illinois	64
Minnesota	63
Mississippi	63
Wisconsin	63
Arkansas	60
Michigan	59
North Dakota	49
All Others	64
United States	68

Source: U.S. Department of Agriculture.

Globally, the most important genetically engineered trait used in transgenic crops is herbicide resistance, which accounted for 69 percent of the total global cropland acres planted with transgenic crops in 1999 (see Table 5). In the same year, insect-resistant crops accounted for about 21 percent of the world's cropland acres

sown with transgenic crops. Crops containing both herbicide-resistant and insect-resistant genes accounted for about seven percent of global cropland acres planted with transgenic crops. Finally, virus-resistant transgenic crops comprised close to three percent of the world's cropland acres sown with transgenic crops.

Table 5. Global Transgenic Crop Traits, by Type, 1999

Trait	Percent of Total Cropland
Herbicide resistance	69
Insect resistance	21
Both herbicide & insect resistance	7
Virus resistance	3

Source: James.

A Controversial Technology

From its beginnings, the implementation of biotechnology has been controversial. Supporters of biotechnology argue that its application in agriculture is necessary to meet a rapidly expanding global demand for food, that it facilitates a reduction in agriculture's dependence on chemicals, that it can help developing nations provide food for their own citizens, and that it can improve global and local food security. Advocates also argue that biotechnology improves the environment, by reducing the need for chemicals in agricultural production. Those in support of biotechnology further argue that the reduced use of pesticides and herbicides, in turn, would reduce human health hazards associated with the use of these chemicals.

Consumers and observers also have raised a series of concerns. Environmental concerns have been raised, including the fear of declining efficacy of the genetic trait in the target species over time. For example, pesticide resistance may develop from increased Bacillus Thuringiensis (Bt) use. Another environmental concern is that the use of the technology may affect non-target species, such as butterflies which depend upon the target species' ecosystem. An additional concern has been referred to as the "super weed" problem, caused by genetic drift to wild relatives of the target species. A final concern is that bioengineered species may have broad environmental impacts by disrupting the natural evolution of valuable species and possibly decreasing their productivity, or causing a proliferation of new genetically modified species and crowding out others.

In addition to environmental concerns, a number of food safety issues have been raised. A number of European countries have banned the importation of many bioengineered products in response to concerns among their citizens about the effects of using biotechnological processes on human health. Thus far, U.S. domestic consumers have been less concerned about the side effects of genetically engineered foods than some of their European, Japanese, and Korean counterparts.

Of direct concern to those in production agriculture is that biotechnology is certain to affect the structure of agriculture. Since the introduction of biotechnology in the mid-1999s, its rapid spread in production agriculture appears to have sped up ongoing structural changes taking place in agriculture. The technology enables agricultural input industries such as seed companies to increase their control over plant production, mitigating agricultural producers' ability to reuse seeds, and leading to reduced control among farmers over their production processes.

Four Principles for Analyzing Biotechnology

In an attempt to put the benefits and the risks associated with biotechnology in perspective, it is useful to keep in mind a set of four principles for analyzing new technologies in general. First is the realization that both proponents and opponents of biotechnology strive toward the same goal–the responsible use of the new technology. Insufficient attempts have been made among groups and individuals for and against the use of biotechnology to acknowledge this fundamental factor, whether in corporate, academic, or government environments. Without this realization, progress will be limited in creating a constructive dialogue among groups and individuals with varying views regarding the extent to which biotechnology should be used in the food and fiber sector. The second principle is that there are valid concerns about, and valid benefits from the impacts of biotechnology. While biotechnology may become an effective tool to alleviate world hunger, it is generally recognized among scientists that pollen transfer to non-targeted crops will occur and that insect resistance to Bt will develop. Acknowledging both benefits and shortcomings of the technology improves the transparency of the discussion. Third, the evaluation of biotechnology and its uses should be based on generally accepted principles that currently exist in the

various sciences for conducting comprehensive system-wide analyses. A fourth principle is to avoid "hype," i.e. that neither the benefits nor the concerns should be overstated. A case in point is "Golden Rice," which was engineered to contain three new genes that together cause rice to produce beta carotene, a precursor of vitamin A. The genetically engineered rice was intended to prevent vitamin A deficiency, a common cause of childhood blindness in developing countries. However, because beta-carotene must be split by an enzyme to become active, and because both beta-carotene and vitamin A are soluble in fat only–requiring a balanced diet containing a sufficient amount of fats and nutrients–Golden Rice alone does not have the ability to eliminate vitamin A deficiency.

Analyzing Costs and Benefits

The benefits of biotechnology must not only be compared to its costs and risks, but the net benefits of biotechnology must also be compared against alternative, appropriate, and locally feasible technologies. Many developing nations have not yet realized potential yield gains from conventional crop improvement efforts due to a lack of research and development capacity. An improved knowledge in conventional agronomic practices may also contribute to rapid yield increases. Finally and perhaps most importantly, no amount of change in technology in agricultural production will relieve world hunger without accompanying political reform that facilitates group and individual access to food.

Domestic and International Consumer Concerns

Agricultural commodities produced with the use of biotechnology are at the center of ongoing trade negotiations and discussions with major U.S. trading partners. Import restrictions and labeling requirements of GMO products are expected to be major agenda items in the next round of WTO trade negotiations. International disagreements about the use of products that are made from transgenic crops have escalated from an increased awareness and public concern about environmental and food safety issues, to a trade conflict between the United States and the other countries. Particular concerns were raised among European nations, but Japan and South Korea also imposed trade restrictions in response to their domestic consumers' concerns about agricultural biotechnology.

In the United States, consumers and the public at large have long held a high degree of confidence in the reliability of their food and fiber system's regulatory process, in part because of ample and safe food supplies. One of the reasons often cited for EU residents' suspicious attitudes towards genetically engineered food products is that there have been a series of well-publicized cases that jeopardized the safety of the food supply in the European Union. For example, food safety concerns developed in response to the Bovine Spongiform Encephalopathy (BSE) or mad cow disease case that started in the United Kingdom in the 1980s and subsequently spread to mainland Europe. Other food safety concerns were raised elsewhere in Europe after sewage sludge, dioxin, and other toxins were fund to have entered the food chain and water supplies in the late 1990s. Perhaps more important than finding the food contaminants themselves was that in each case, government officials attempted to reassure consumers about the safety of the food supply, only to be proven wrong later. Even more important is that most European nations have historically not had central regulatory agencies that would oversee the safety of the food supply, or equivalents to the U.S. Food and Drug Administration. As a consequence, many European nations were left to regulate and impose restrictions on final products, rather than the process in which the product is produced, which is the case in the United States.

The European experience suggests that a major challenge today in the development of agricultural biotechnology in the United States, is to maintain public and consumer confidence in the regulatory and research system. While the StarLink case may have been "an accident waiting to happen," it does indicate system weaknesses that need to be addressed in the U.S. agricultural system, which has traditionally not made a distinction between two seemingly identical raw agricultural products that were destined for separate food and feed markets. Further, it is likely that U.S. confidence in the regulatory system will also decline if similar events occur.

Concluding Remarks

The discussion on the merits and risks of agricultural biotechnology will require the involvement of all participants in the food and fiber system, from agricultural producers to consumers of final products. Scientific justification of biotechnology's merits is a necessary condition for its successful implementation, but it is not sufficient.

An additional requirement is that stakeholder concerns–including those of developing nations, environmental groups and consumers–are addressed in an open and transparent manner.

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